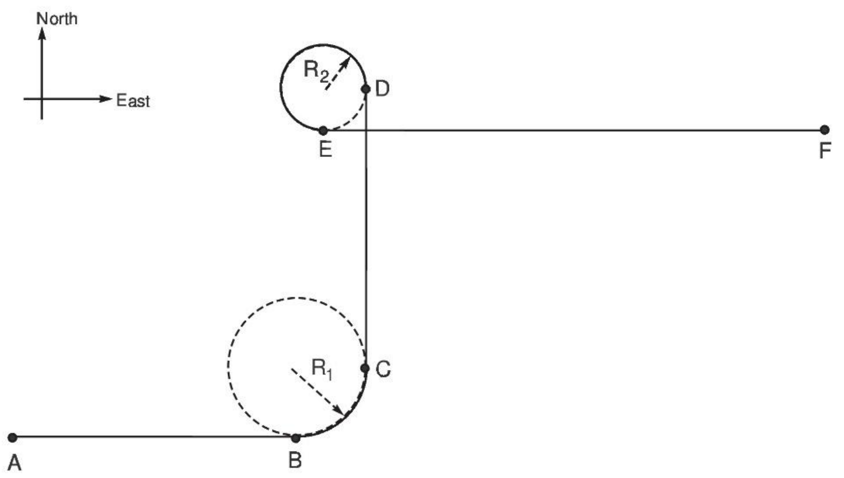
Sistemas de Controlo de Tráfego 2020-21

Project 1 – Receiver positioning in GPS

The project consists of implementing a simulator of an aircraft trajectory with the following major tasks:

- Generation of a GPS satellite constellation for a given pre-defined time with the use of almanacs obtained, for instance, in Celestrak.com.
- Determination of the satellites in view (N_{view}) from a selected location on the Earth surface.
- Determination of the optimum sub-constellation for a certain number of satellites N selectable (with $N_{view} \geq N \geq 4$) using minimization of the PDOP parameter.
- Implementation of the least-squares and extended Kalman filter (EKF) algorithms (models PV and/or PVA) using the pseudoranges with imperfect ionospheric/tropospheric corrections as observations.
- Estimation of the receiver's position (latitude, longitude, and altitude), velocity (and acceleration for PVA model) using the least-squares and the EKF. Consider the following trajectory ABCDEF:



where:

$\overline{AB}$ (20 km) – Uniformly accelerated motion with acceleration $a = 1\ \mathrm{m/s^2}$ and initial velocity $v_0 = 75\ \mathrm{m/s}$ (use mask angle=10 degrees);

$\overline{BC}$ – Circular motion with constant angular speed (use mask angle=10 degrees) (radius $R1 = 5\ km$);

$\overline{CD}$ (20 km) – Uniform motion with constant speed (use mask angle=10 degrees);

$\overline{DE}$ – Circular motion with constant angular speed (use mask angle=10 degrees) (radius $R2 = 3\ km$);

$\overline{EF}$ (36 km) - Uniform motion with constant speed (canyon scenario).

- Performance comparison of the estimation algorithms. Repeat the simulations $N_{sim} = 100$ times with independent Gaussian pseudorange additive noises and determine the rms values of the receiver's position and velocity estimation errors for each sampling time. Note that, in the least-squares algorithm, the velocity estimates may still be obtained from the adjacent position estimates although with large estimation errors.
  If applicable, compare the performance achieved with the least-squares algorithm and the Kalman filtering.

Algorithms to be implemented

- For groups with 1 student
  a) Least-squares algorithm

- For groups with 2 students (optional for groups with 1 student)
  a) Least-squares algorithm
  b) Extended KF (model PV)

- For groups with 3 students (optional for groups with 2 students)
  a) Least-squares algorithm
  b) Extended KF (model PV)
  c) Extended KF (model PVA)

Notes:

The pseudoranges are updated (sampled) at the rate of 2 Hz.

The receiver's initial position (A) has the following coordinates: 39 degrees North, 8 degrees West and altitude h=3500 m. The motion is performed in the horizontal plane.

The path $\overline{EF}$ represents the trajectory in a canyon scenario where only the $N_{view} = 4$ satellites with the higher elevation angles are in view.

The receiver's clock is a quartz temperature-compensated oscillator. The clock time errors should be simulated with the usual 2-state model.

The corrected pseudoranges (with minimized ionospheric/tropospheric errors) of the N satellites in view are disturbed by additive gaussian errors, modelled as

$$n_i(k) = \bar{n}_i(k) + \tilde{n}(k)f(\varepsilon_i), \quad i = 1, \dots, N, \quad k = 0,1, \dots, k_{max}$$

where i is the satellite index, k is the sampling time index, $\bar{n}_i(k)$ are independent, gaussian, zero-mean **white sequences** with common variance $7\sigma^2/8$ and $\tilde{n}(k)$ is a slowly varying, zero-mean, gaussian process. For simplicity, assume that this quantity is constant for all the satellites during each trajectory, that is, $\tilde{n}(k) = \tilde{n}$, but changes between trajectories. The obliquity factors are given by

$$f(\varepsilon_i) = \frac{1.1}{\sin(\varepsilon_i) + 0.1}$$

where ε_i is the elevation angle of satellite i.

Analyse the effect of decreasing the number of satellites in view on the position and velocity estimates in path $\overline{DE}$, provoked by the canyon, by repeating the simulations but considering now that the angle mask is equal to 10 degrees in the path $\overline{EF}$ (absence of canyon).

Analyse the effect of the ionospheric errors on the position, velocity (and acceleration) estimates, by repeating the simulations with $\tilde{n}(k) = 0$.

Note: Due to the short duration of the aircraft trajectory, it is sufficient to determine the best subset of satellites at the beginning of each trajectory.

Bibliography:

F. Nunes, SCT Notes, IST, 2020.

E. Kaplan, C. Hegarty, "Understanding GPS. Principles and Applications", second edition, Artech House, Boston, 2006.